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A TDMA Adaptive Directional Antenna Array for Multipath Mitigation

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The present invention discloses a method and device for the mitigation of code and carrier-phase multipath in ranging signals. The present invention has particular, but not exclusive application in positioning technologies where precise range information free from multipath perturbations are essential for accurate positioning.

Background to the Invention

Multipath in an indoor environment is severe, with high power signals being reflected from most objects including walls, furniture and people. Traditional diversity methods are not sufficient to mitigate poor carrier range measurements in high multipath environments, as integrated carrier phase techniques require the direct line-of-site signal to be measured. The unintentional measurement of off-axis multipath signals corrupt the integrated carrier phase measurements, which leads to significant degradation in the accuracy of carrier range and velocity measurements. Furthermore, strong off-axis multipath reflections cause severe code-based pseudorange biases, which can substantially degrade absolute position accuracy. Therefore, a system which mitigates off-axis reflections is highly desirable in an indoor positioning system.

Disclosure of the Invention

The present invention discloses a method and device to mitigate code and carrier phase multipath by steering a directional receive antenna in spatial and chronological synchronization with a plurality of Time Division Multiple Access (TDMA) positioning-unit device transmission sources. The directional receive antenna is controlled by a deterministic algorithm based on knowledge of the TDMA sequence, antenna array location, antenna array orientation (attitude), positioning-unit device locations, and network time.

A plurality of chronologically synchronized positioning-unit devices, positioned at known locations, transmit positioning signals in a predetermined TDMA sequence, such that each transmitter has a unique transmission time slot. A position receiver is configured to receive TDMA positioning signals from the network of positioning-unit devices and determine position, velocity and network time. The position receiver is also configured with a TDMA adaptive directional antenna array, capable of producing a directional beam pattern, which can be successively pointed in a plurality

of directions. The directional beam pattern is sequentially switched to follow the TDMA sequence of the positioning-unit device transmissions, such that the directional receive pattern is always oriented toward the current transmitting positioning-unit device. An Inertial Navigation System is also configured with the position receiver to provide orientation (attitude) information for the antenna array. With location, orientation, time, and TDMA information available the position receiver spatially and chronologically synchronizes the antenna array to the TDMA transmission sequence of the network of positioning-unit devices. As the position receiver location and attitude changes the antenna beam azimuth and elevation adjusts to follow the positioning-unit device transmissions.

Referring now to FIG 1., a network of chronologically synchronized positioning-unit devices 101 transmit TDMA positioning signals 102 to a position receiver 103. The position receiver 103 incorporates a TDMA adaptive directional antenna array 104 and an Inertial Navigation System (INS) 105. The position receiver 103 initially performs a coarse position, velocity and time (PVT) solution to determine coarse elevation and azimuth information for all positioning-unit devices in-view 101 and coarse network time. The position receiver 103 also determines antenna array 104 orientation (attitude) by processing data provided by the INS 106. The position receiver 103 also determines each positioning-unit device's 101 TDMA transmission sequence by interrogating navigation data transmitted from each positioning unit device 101.

Referring now to FIG 2., the position receiver 203 determines which positioning-unit device 201-1 will transmit the next positioning signal 202-1 and from which direction the positioning signal will arrive. The position receiver 203 subsequently points the directional antenna array 204 beam pattern 205 in the direction of the positioning-unit device 201-1 at the commencement of transmission. The position receiver 203 then determines which positioning-unit device will transmit the next positioning signal 201-3 and from which direction the positioning signal will arrive 206. The position receiver 203 subsequently points the directional antenna array 204 beam pattern 205 in the direction of the positioning-unit device 201-3 at the commencement of transmission. This process continues ad infinitum.

Accurate location and time can now be determined by the position receiver by performing a position, velocity and time (PVT) solution while the array is synchronized. Off-axis multipath is substantially mitigated, allowing much higher accuracy code and carrier position solutions than identical receivers that do not incorporate a TDMA Adaptive Directional Antenna Array.

TDMA Adaptive Directional Antenna Array

In a first embodiment the TDMA Adaptive Directional Antenna Array incorporates a plurality of spatially distributed antenna elements with adjustable phase and amplitude. This form of adaptive array is known as a "phased array" and is well known in the art.

In a second embodiment the TDMA Adaptive Directional Antenna Array incorporates a driven element and a plurality of spatially distributed parasitic elements. A parasitic element is switched on by shorting the element to ground, which changes the pattern of the array. This form of adaptive array is known as a "switched parasitic antenna array" and is also well known in the art.

In a third embodiment the TDMA Adaptive Directional Antenna Array incorporates a plurality of beam antennas, facing in a plurality of directions. In this embodiment the antenna which faces the currently transmitting positioning-unit device is switched on, with all other antennas switched off.

Acquisition of TDMA positioning signals

A coarse location and time is determined by the position receiver by first performing a position, velocity and time (PVT) solution while the array is not synchronized. At this time the array is configured in an omni-directional pattern. The position receiver can now determine coarse elevation and azimuth information for all positioning-unit devices in-view, and coarse network time.

INS

The position receiver determines orientation of the antenna array via its Inertial Navigation System (INS). The INS may include devices such as fluxgate compasses, magnetometers, accelerometers, and rate gyros.

TDMA Determination

The TDMA pulse sequence of each positioning-unit device is transmitted in its navigation message. The position receiver determines TDMA sequences by interrogation of the navigation message from each positioning-unit device.

Alternatively, the TDMA pulse sequence may be associated with the positioning-unit device PRN code. In this embodiment the position receiver determines TDMA sequence by associating a received PRN code with a predetermined TDMA sequence.

Chronological Synchronization

The knowledge of current network time and TDMA sequence allows the position receiver to chronologically synchronize the antenna array with the positioning-unit device TDMA transmissions.

Spatial Synchronization

The knowledge of position and orientation allows the position receiver to spatially synchronize the antenna array to the network by steering a directional beam toward the currently transmitting positioning-unit device.

Adaptive Beam-width

In a further embodiment of the present invention the beam-width of the directional antennas may be dynamically adjusted depending on position receiver circumstance. As position and time are determined more accurately by the position receiver the azimuth and elevation to each positioning-unit device will also become better known. Consequently the beam-width of the array can be narrowed to mitigate further multipath.

TDMA Pulse Sequence

Each positioning-unit device pulses its transmission in a TDMA sequence. In the preferred embodiment a 100 microsecond pulse is transmitted every 1 millisecond. This gives a 10% pulse duty cycle with 10 available slots. The position receiver interrogates each positioning-unit device navigation message to determine the respective TDMA slot positions.

Conclusion

With both spatial and chronological synchronization of the TDMA Adaptive Directional Antenna Array, the position receiver can determine high accuracy PVT solutions in high multipath conditions.

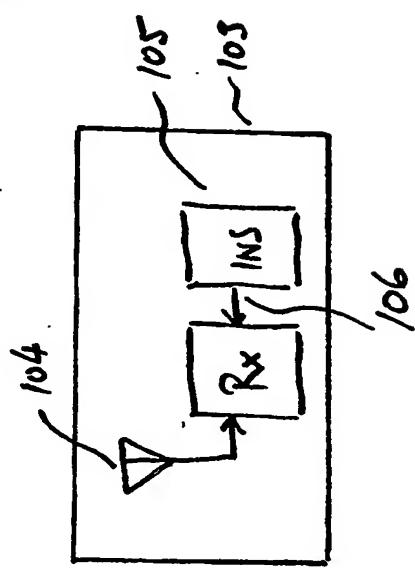
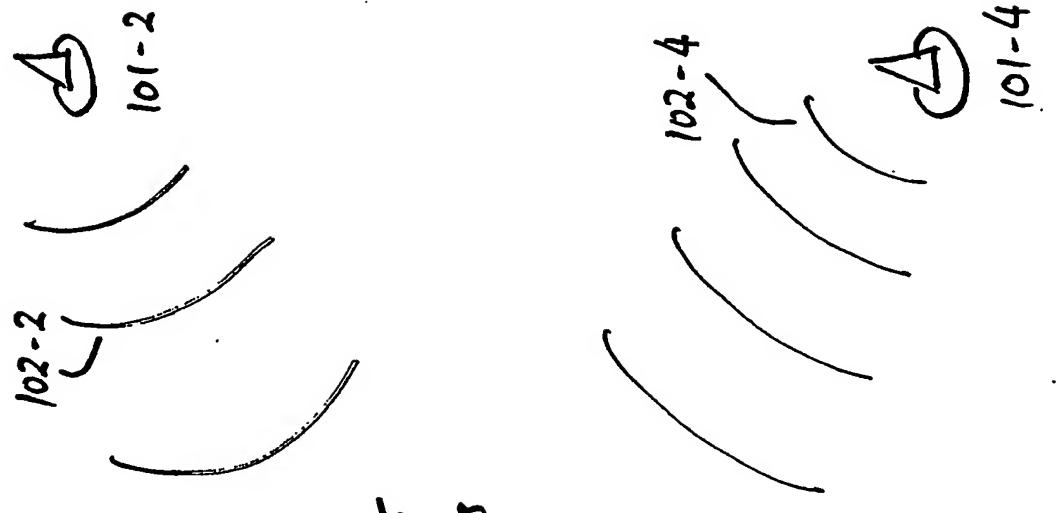


FIG. 1



Δ
201-2

Δ
201-4

Δ
201-1

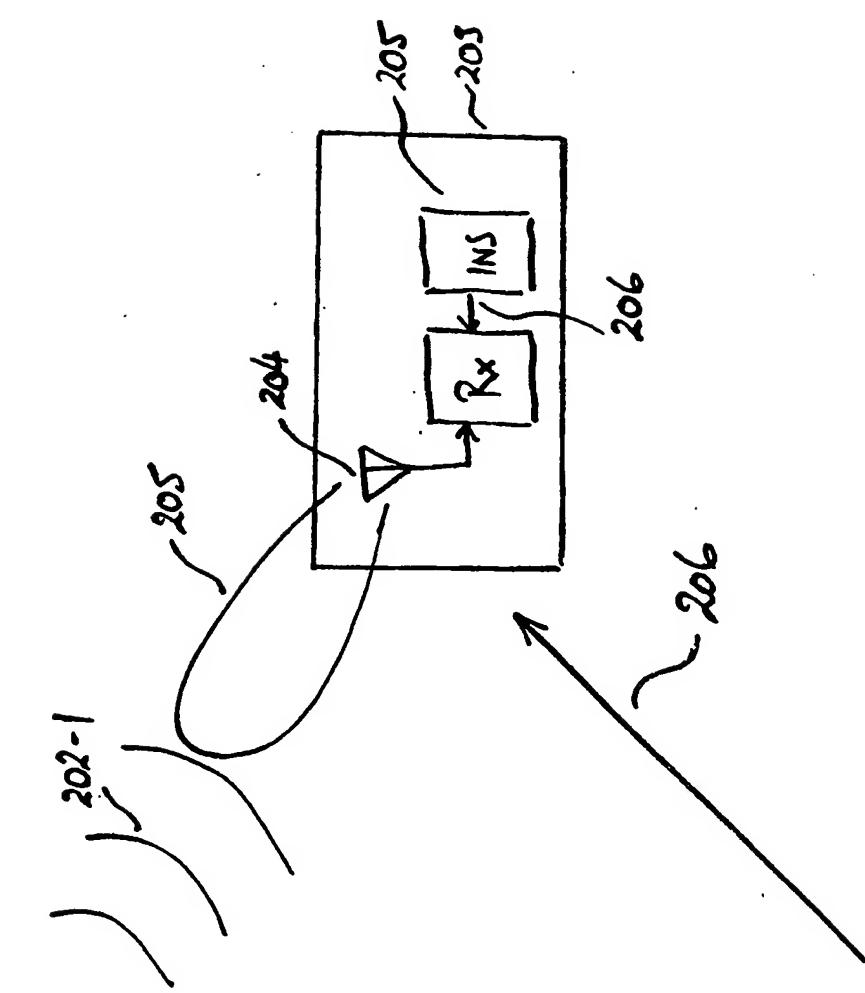


Fig. 2

Δ
201-3